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(54) Electromagnetic Position Transducer Uses Eddy Currents Induced in Conductive Member

(57) In an electromagnetic transducer the position of a conductive body in a time-varying magnetic field is sensed by detecting the reduction of the sum of e.m.f.s induced in a pair of series-opposed pick-up windings due to the magnetic field produced by eddy currents induced in the conductive body. In a first embodiment, measuring liquid level, the body is a metal tube 14 on a float 5 sliding along an elongate core 6 supporting an energising coil 7 and the secondaries 9, 10. Alternatively the three coils are wound on respective parallel rectangular ferromagnetic blocks and the conductive body is moveable between the energising coil and one of the series-opposed secondaries.

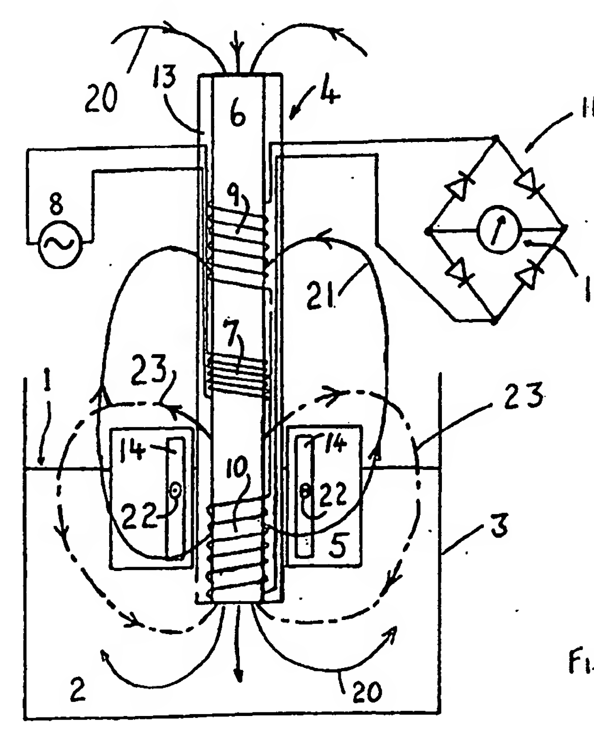

Fig. 1

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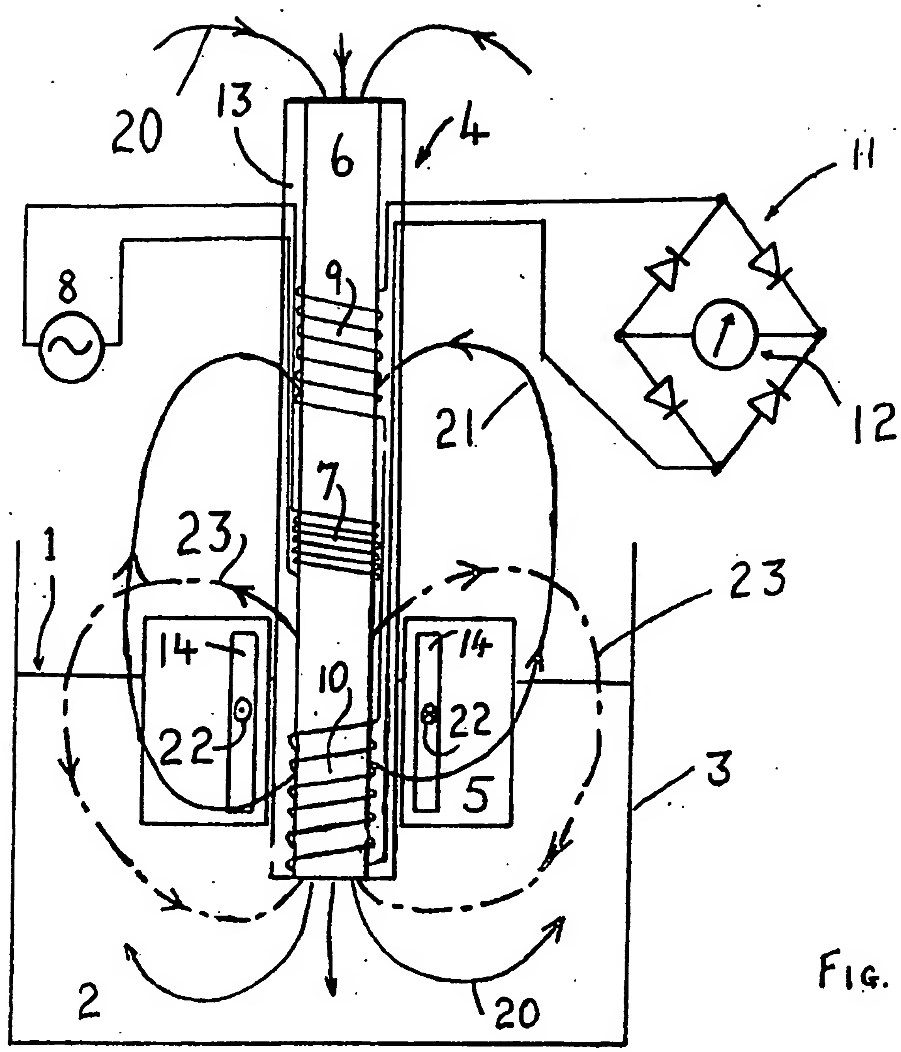

Fig. 1

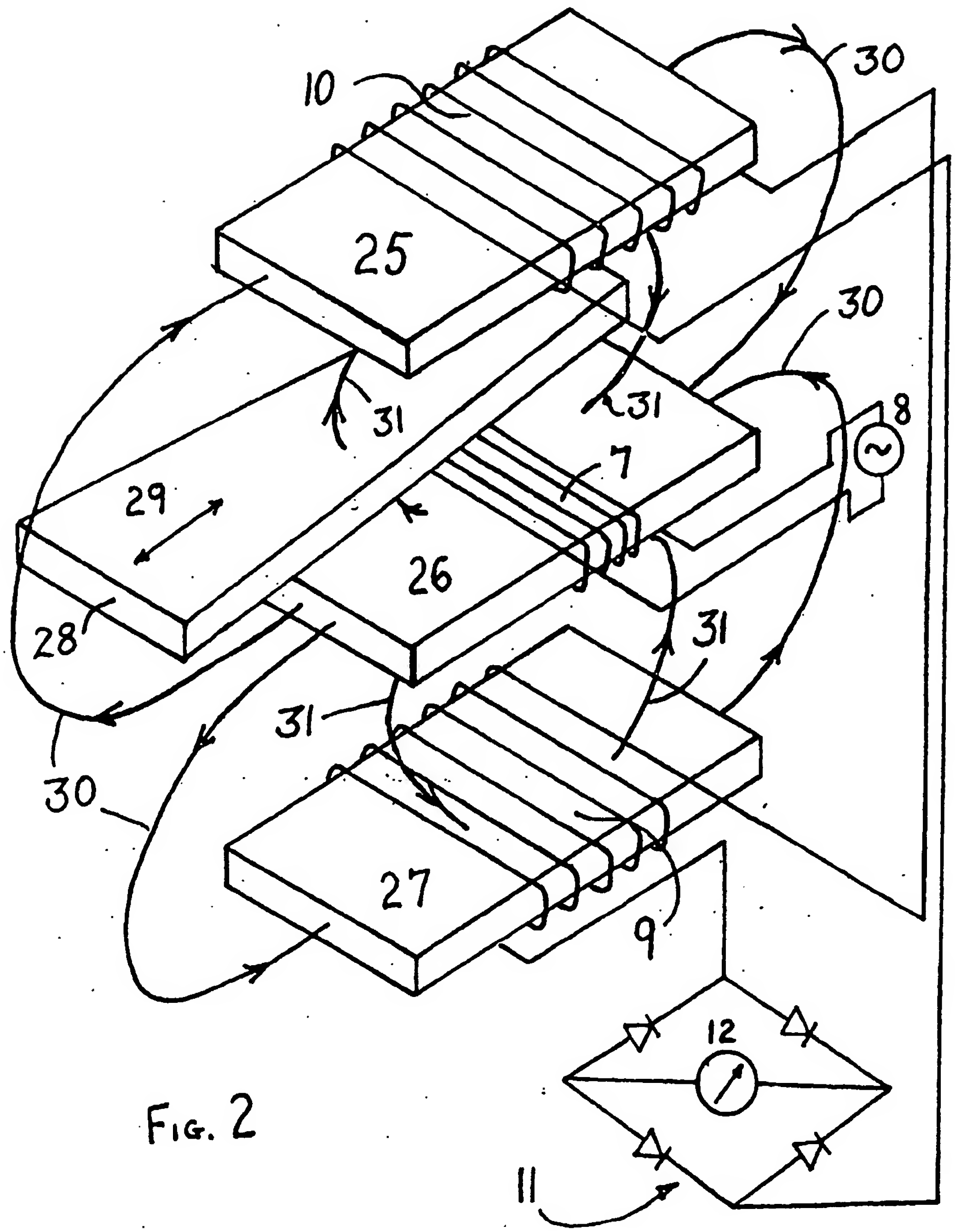

Fig. 2

SPECIFICATION
Electromagnetic Position Transducer

The present invention relates to an electromagnetic position transducer which is able to very accurately measure small changes in position of a member or body which is movable through the comparatively large stroke.

As such, the present invention finds application in a wider number of fields but particularly in instrumentation where the invention may be used in liquid level measuring devices, strain gauges, and other similar such instruments.

A fundamental problem associated with such instruments is to find a suitable transducer which permits small changes in the position of a float, or small changes in the length of a strain gauge element, to be easily converted with high sensitivity into an electrical output which may then be easily processed or displayed.

It is the object of the present invention to provide such a transducer and to thereby overcome the above mentioned problem.

According to one aspect of the present invention there is disclosed an electromagnetic position transducer comprising means to create a time-varying magnetic field, first and second coils each disposed in said time-varying field to have an emf induced therein, said coils being connected in series across an electric metering device the output of which is indicative of the algebraic sum of said induced emfs, and a conductive member movable in said time-varying field relative to at least one of said coils and positioned relative to said one coil and said time-varying field such that eddy currents are induced by said time-varying field in said conductive member, said eddy currents inducing a further magnetic field in said one coil which reduces the nett emf induced therein, thereby changing said algebraic emf sum whereby the output of said metering device indicates the position of said conductive member.

Two embodiments of the present invention will now be described with reference to the drawings in which:

Figure 1 is a schematic illustration of a liquid level measuring instrument which embodies the present invention, and

Figure 2 is a schematic perspective view of a further embodiment of the position transducer of the present invention.

Figure 1 illustrates an embodiment of the invention which may be used to measure the level 1 of liquid 2 held within a tank 3. A rod 4 is vertically positioned within the tank 3 and has a cylindrical tubular float 5 slidably positioned thereon. The float 5 is illustrated in cross section in Figure 1 and contains a length of metal tube 14 which is coaxial with the core 6.

The rod 4 is partly illustrated in cross section in Figure 1 so as to show a ferromagnetic cylindrical core 6 about which a centrally located field winding 7 is wound. The field winding 7 is connected across an AC voltage generator 8.

Two coils 9 and 10 are transversely wound around the core 6 and positioned one to either side of the field winding 7. The coils 9 and 10 preferably have identical numbers of turns, and are connected in series opposing connection across a diode bridge 11 in which a DC meter 12 is connected.

The core 6 is covered by a protective cylindrical coating 13 of plastics, of similar non-magnetic material, which encapsulates the field winding 7 and coils 9 and 10. In addition, the cylindrical coating 13 provides a surface upon which the float 5 may slide up and down along the rod 4 in response to changes in the level 1 of the liquid 2 held within the tank 3.

When the generator 8 supplies an AC current to the field winding 7, an alternating magnetic field is set up within the core 6. This field may conveniently be considered to comprise two fields, a main field, the flux lines of which are indicated at 20 and which link all the turns of both coils 9 and 10, and a leakage field of which the flux lines 21 do not link all the turns of the coils 9 and 10. In Figure 1 the direction of the flux lines 20 and 21 is indicated by means of arrows at an instant of time, however, the direction of the magnetic flux will change at the frequency of the AC voltage generator 8.

If the float 5 and metal tube 14 were not present, the emf induced in coil 9 would be equal to, but of opposite polarity to, the emf induced in coil 10. Thus these induced emf's would cancel each other and no current would flow through the meter 12.

The metal tube 14, which is preferably made of light weight highly conductive metal such as aluminium, may be considered to be a single turn of a winding which is magnetically coupled to the core 6. As a result, the changing magnetic flux which passes through the core 6 also links the metal tube 14 and therefore sets up an eddy current 22 which is coaxial with the core 6. The direction of flow of the eddy current 22 at the moment illustrated in Figure 1 is indicated in conventional fashion.

The flow of eddy current 22 induces a magnetic field the flux lines 23 of which are indicated by dot and dash lines in Figure 1. The induced field 23 is of opposite polarity to that of the main field 20 and leakage field 21 so that the nett amount of flux passing through the core 6 and linking the turns of the coil 10 is reduced. As a result, the magnitude of the emf induced in the coil 10 is reduced. In consequence, the algebraic sum of the emf induced in coil 9 and the emf induced in coil 10 is no longer approximately zero. Therefore a current flows in the coils 9 and 10 which causes deflection of the meter 12.

The magnitude of the induced eddy current 22 is dependent upon the position of the float 5 relative to the core 6. Furthermore, not only is the magnitude of the induced field 23 dependent upon the magnitude of the induced eddy current 22, but the effect of the induced field 23 on the voltage generated within coil 10 also depends

upon the position of the float 5 relative to the coil 6.

When the level 1 of the liquid 2 in the tank 3 is very low, the float 5 will only just engage the end of the rod 4. Therefore only the main magnetic field 20 is available to induce the eddy current 22 so that the magnitude of the eddy current 22 will be low. Furthermore the induced magnetic field 23 will not link all the turns of the coil 10 and therefore the change in the emf induced in the coil 10 will not be great. However, as the float moves upwardly along the rod 4 in response to an increasing level 1 of the liquid 2, then more and more of the leakage flux 21 will be available to increase the magnitude of the induced eddy current 22. Furthermore, the induced field 23 will progresively link more and more of the turns of the coil 10.

As a result of the foregoing, the current indicated by meter 12 will increase as the level of liquid 2 increases and therefore the magnitude of the current indicated by the meter 12 provides a direct reading of the level 1 of liquid 2 within the tank 3.

Figure 2 is a schematic perspective view of a second embodiment in accordance with the present invention. Three rectangular blocks 25 to 27 of ferromagnetic material are positioned in three spaced parallel planes as illustrated in Figure 2. The blocks 25 to 27 may be maintained in the positions shown by any conventional non-magnetic supporting arrangement (not illustrated). Block 26 carries the field winding 7 which, as before, is connected to AC generator 8. Blocks 25 and 27 respectively carry coils 10 and 9 which are again of equal number of turns and connected in series opposition across diode bridge 11 and meter 12. A conductive wedge-shaped member 28 is removably insertable is indicated by arrow 29 between blocks 25 and 26 and substantially parallel thereto.

As before, the alternating current flowing in field winding 7 induces a magnetic field which may be conveniently considered to comprise a main field having flux lines 30 as indicated which link all the turns of coils 9 and 10, and a leakage field having flux lines 31 indicated which do not link all the turns of coils 9 and 10.

In the absence of wedge-shaped member 28, because of the symmetry of the construction, the emf induced in coil 9 and the emf induced in coil 10 will be of equal magnitude but opposite polarity and therefore no current will flow through the meter 12. However, as wedge-shaped member 28 is inserted between blocks 25 and 26, an alternating magnetic field will pass through the wedge-shaped member 28 thereby inducing eddy currents therein. The direction of flow and the polarity of the eddy currents will be such that the eddy currents will induce a magnetic field. This induced magnetic field will be of direction and polarity such that the magnetic field which induced the eddy current is opposed.

In consequence, the flow of eddy current within the wedge-shaped member 28 acts to reduce the magnetic field which links the turns of the coil 10, thereby reducing the magnitude of the emf induced in that coil. As a result, the previous cancellation of the induced emfs no longer takes place and a resultant current flows in the meter 12. The magnitude of this current will be dependent upon the position of, or degree of insertion of, the wedge-shaped member 28.

By making the member 28 wedge-shaped as illustrated, a linear relationship may be achieved between the current flowing in the meter 12 and the departure of the wedge-shaped member 28 from a rest position at which the wedge-shaped member 28 begins to approach blocks 25 and 26 without causing any current to flow in meter 12.

The sensitivity of the apparatus of the embodiment of Figure 2 may be increased by making the wedge-shaped member 28 of ferromagnetic material. When this occurs, part of the leakage flux 31 will be constrained to flow entirely within the wedge-shaped member 28 and will therefore not link any of the turns of coil 10. In consequence there will be a larger difference between the emf induced in coil 9 and that induced in coil 10. Therefore a larger current will flow in the meter 12.

As the wedge-shaped member 28 is inserted further into the space between blocks 25 and 26, more and more of the leakage flux 31 will pass through the wedge-shaped member 28 thereby inducing eddy currents of large magnitude. Therefore the nett flux passing through coil 10 will be reduced and the current flowing through meter 12 thereby increased in response to the increasing insertion of the wedge-shaped member 28.

The foregoing describes only two embodiments of the present invention and modifications, obvious to those skilled in the art, may be made thereto without departing from the scope of the present invention. For example, the number of turns in coils 9 and 10 need not be equal nor need coils 9 and 10 be connected in series opposed connection. These two conditions are desirable if a zero current reading on meter 12 is required to indicate the absence of wedge-shaped member 28, or no liquid 2 in the tank 3, for example. If the coils 9 and 10 were connected in series aiding connection, a relatively large current would be indicated on the meter 12 in the absence of wedge-shaped member 28 and this large current would be progressively reduced by the insertion of the wedge-shaped member 28. It will therefore be seen that the requirement of equal number of turns and series opposing connection for the coils 9 and 10, although desirable to produce a convenient meter reading, are not essential to the working of the present invention.

Furthermore, although the generator 8 is indicated as being a sinewave generator, a chopped D.C. source is sufficient and the distorted current waveform supplied by such a source provides slightly improved sensitivity in the apparatus of Figure 2. It is thought that this result

comes about because of the presence of higher frequency harmonics in the current waveform and hence in the magnetic fields. It will be seen from the foregoing that it is only necessary for the magnetic fields to be time-varying in order to produce the necessary inductive effects. It is not necessary for the magnetic fields to be strictly alternating in that a change of polarity is not required. For example, the chopped D.C. voltage supplied to the primary winding of a conventional automatic ignition coil provides an adequate voltage source for the field coil 7.

Claims

1. An electromagnetic position transducer comprising means to create a time-varying magnetic field, first and second coils each disposed in said time-varying field to have an emf induced therein, said coils being connected in series across an electric metering device the output of which is indicative of the algebraic sum of said induced emfs, and a conductive member movable in said time-varying field relative to at least one of said coils and positioned relative to said one coil and said time-varying field such that eddy currents are induced by said time-varying field in said conductive member, said eddy currents inducing a further magnetic field in said one coil which reduces the nett emf induced therein thereby changing said algebraic emf such whereby the output of said metering device indicates the position of said conductive member.

2. A transducer as claimed in claim 1 wherein said first and second coils are connected in opposition and have substantially equal numbers of turns thereby providing a zero output indicative of a predetermined position of said conductive member.

3. A transducer as claimed in claim 1 or 2 wherein said means to create a time-varying magnetic field comprises a field coil wound transversely around an elongated permeable member, said field coil being connectable to a time-varying current source.

4. A transducer as claimed in claim 3 wherein said first and second coils are wound transversely around said elongated permeable member.

5. A transducer as claimed in claim 4 wherein said conductive member has an aperture therethrough, said conductive member being movable along said elongated permeable member by passage of the latter through said aperture.

6. The transducer as claimed in claim 5 wherein said elongated permeable member comprises a ferromagnetic cylinder, said field coil is positioned between said first and second coils, and said conductive member comprises a cylindrical tube slidable along said rod.

7. The transducer as claimed in claim 6 wherein said conductive member is connected to a float, and said rod is vertically mounted within a liquid carrying container, the position of said conductive member being indicative of the level of said liquid.

8. A transducer as claimed in claim 2 or 3 wherein said first and second coils are respectively transversely wound around first and second elongated permeable bodies, said bodies being spaced one to either side of, and substantially parallel to, said elongated member, and said conductive member being insertable between one said body and said elongated member.

9. The transducer as claimed in claim 8 wherein said conductive member has a longitudinal axis parallel to said elongated member and tapers in the direction of said longitudinal axis.

10. The transducer as claimed in any one of the preceding claims wherein said conductive member is ferromagnetic.

11. An electromagnetic position transducer substantially as described with reference to Figure 1 or 2 of the drawings.

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